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A QUALITY PHILOSOPHY FOR INTEGRATED PRODUCT DEVELOPMENT

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Total Quality Management (TQM) is a major DoD initiative to instill quality practices in DoD management and processes. Concurrent Engineering (CE) is a critical component under the TQM umbrella targeting the design and acquisition efforts supporting DoD. TQM and CE, or Integrated Product Development (IPD), share some fundamental characteristics, namely, (1) management commitment, (2) continual improvement, (3) customer satisfaction, (4) teamwork, (5) focus on work processes, (6) training, (7) the recognition that people are the critical resource of an organization, and (8) the understanding that there is no blueprint for success. These shared characteristics are discussed to support the theory that IPD is TQM applied to the product design process.

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PREFACE

This paper discusses the relationship between Total Quality Management (TQM) and Concurrent Engineering (CE), or Integrated Product Development (IPD). The ideas herein were developed over two years through my experience as both TQM coordinator for the Logistics Research Division and lead scientist for the decision support systems effort within the Acquisition Logistics Branch. During this time I had the pleasure of working with David Dierolf and Karen Richter of The Institute for Defense Analyses (IDA); their comments on the ideas developed in this paper are appreciated. In fact, their research efforts under the Formal Methods and DSS Tools work unit (2940-01-19) formed the basis for the IDA Paper, P-2506, Concurrent Engineering Teams, and the joint article "Concurrent Engineering: Total Quality Management Applied to Product/Process Definition" (to appear in Concurrent Engineering, Auerbach Publishers). This technical paper however delves much more deeply into the philosophical comparisons between TQM and IPD. It is hoped that readers will use the views and opinions expressed in this paper, along with the aforementioned companion works, to ease efforts to initiate the IPD process.

SUMMARY

This paper compares the philosophical basics of Total Quality Management (TQM) and Concurrent Engineering (CE), or as referred to in the DoD, Integrated Product Development (IPD). TQM is a critical initiative for American industry and the Department of Defense (DoD). American industry faces a "crisis" in industrial competitiveness in the global market; a return to quality products and processes is seen as a long-term solution to this crisis. Similarly, the DoD is facing its own challenges, such as declining resources to meet expanding demands. TQM is the DoD initiative in quality to help answer these and future challenges. Integrated Product Development (IPD), is a component method under the TQM umbrella that targets the design environment. The IPD approach provides: (1) better coordination between interdependent design activities, (2) better support and tracking of product evolution, and (3) simultaneous coordination of all product life-cycle elements. A closer examination of TQM and IPD reveals similarities in underlying philosophies which lead to characterizing IPD as TQM applied to product design. To support this characterization, seven fundamental tenets of TQM are discussed:

(1) management commitment,

(2) continual improvement,

(3) customer satisfaction,

(4) teamwork,

(5) work processes,

(6) training, and

(7) people as the critical resource.

Each tenet is discussed and its IPD applicability is identified.

A QUALITY PHILOSOPHY FOR INTEGRATED PRODUCT DEVELOPMENT

I. INTRODUCTION

There is a tremendous push, both within American industry and the Department of Defense (DoD), to improve the quality of all goods and services in an effort to improve industrial competitiveness in an increasingly competitive, international market. This push is known by various names (Q+, TEX, TQ, PIQE) [Ropelewski, 1990] and each particular instance of quality improvement is unique in some way. However, each improvement initiative shares common themes. Each initiative seeks to meet the technological and economic challenges of the modern international marketplace by focusing on the quality of the products produced, the quality of the processes employed to produce the products, and the quality of the people and management system within the organization. Within the DoD, the quality improvement process is called Total Quality Management (TQM). Although TQM is new doctrine for DoD, formally adopted in 1988 [Carlucci, 1988], its philosophies are already a success story. The most notable success is the emergence of Japan as an international industrial power.

A key technology of TQM is Concurrent Engineering (CE), or Integrated Product Development (IPD).[1] IPD is a technique whereby system design defects are avoided rather than corrected later in the design process. The IPD approach is to define the product characteristics while defining the processes by which the product will be manufactured and supported. The potential of IPD is tremendous. It empowers the design organization, and more importantly the people of the design organization, to examine all life-cycle considerations of a proposed system during the early stages of design while there is still time to make cost-effective changes to the system. In effect, CE focuses on improving the end product by improving the process by which it is designed and built. TQM shares this same focus.

Thus, IPD is characterized as TQM applied to the product design process. The objective of this paper is to acquaint the reader with the IPD philosophy. This will be accomplished by relating the basic tenets of TQM to the IPD initiative. Prior to discussing this relationship between TQM and IPD, it will be helpful to briefly explain the history of TQM and IPD.

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[1]Recently, concurrent engineering has been referred to as Integrated Product Development (IPD). The two terms are effectively synonymous and use of IPD within this paper implies either term.

II. TOTAL QUALITY MANAGEMENT

The history of TQM has already been aptly descibed by various authors. This paper will not analyze and synthesize the various views and opinions on the subject; rather, it will identify a few keys points that will help to establish our particular perspective on the subject.

American industry collectively suffered complacency after World War II (WWII) with respect to quality. Post-WWII prosperity resulting from consumer markets eager for goods, coupled with America having the only intact industrial base, lulled American industry into a false sense of security. American products were then the best in the world feeding a hungry market. Thus, managers focused their concern on schedules and short-term profits, often at the expense of quality. Unfortunately they got away with this practice. The result is a mindset, now prevalent in business practices, that emphasizes quick return on investment, maximization of stockholder premiums, a lack of long-term investment focus, and a sometimes Tayloristic approach to management wherein management is responsible for everything in the organization. Meanwhile, America's competition, most notably Japan, rebuilt after the war with a focus on quality management practices. These companies made the necessary long-term, initially low-yield, investments in manufacturing technology and empowered the entire design and production organization to seek continual improvement. These companies now have advanced manufacturing technology. The result is that new products are often introduced by American firms but efficiently, and competitively, manufactured abroad. American firms thus lose market share and the associated profits. The result is a "crisis" in American productivity resulting from intense foreign competition and loss of American market share in various manufacturing industries.

Government and Industry have attacked this crisis in various ways. Higher tariffs on imports is one method, but protectionism does not help industry in the long run. Factory automation has achieved marginal success, but often at substantial financial cost. New research and innovations are another method; recent industry-academia research consortia is a promising outgrowth of this approach. However, the most promising method is to focus on quality improvement. Authors such as Peters, Juran, Crosby, and Deming are telling American industry how to re-focus their efforts on quality and quality management practices. Their message is clear: accept the "new" philosophy or American manufacturing will cease to be among the world leaders.

The DoD has a vested interest in the health of American industry and its manufacturing capabilities. The DoD is the largest customer of, and largest supplier to, the American industrial base [Perry, 1986], so much so that it "is often difficult to draw a clear-cut distinction between the U.S. defense industrial base and the U.S. commercial manufacturing economy" [McCormack, 1989]. In times of declining budgets and perceived lessening of defense requirements, production runs for weapon systems are short and very specialized. Austere and inconsistent budgets cause lengthened production runs of less than optimal output efficiency. This burden is placed on manufacturing facilities that are essentially specific to a product. Our lack of long-term investment in manufacturing technology means that today we still (for the most part) work with a 1940s mindset of long-running, high-yield, single-product production lines. But the DoD continually loses the cost savings of mass production.

Another reason for DoD interest in the American industrial base is that "the ability of our military forces to meet our national security objectives is, in large measure, a function of the strength and vitality of U.S. Industry" [Strickland, 1988]. The DoD war machine is only as strong as the ability of the American industrial base to support surge production to meet wartime demands, particularly in the highly specialized sectors of industry the DoD relies on. Insufficient factories, lack of modern equipment in the existing factories, too few flexible manufacturing plants, and foreign-owned American factories pose threats to national security. To adequately meet defense procurement needs, the American manufacturing environment must be flexible enough to effectively and efficiently produce weapon systems in the required small lots.

TQM is a "strategy for improving the quality of DoD processes and products and achieving substantial reductions in the cost of ownership throughout the systems' life cycle" [Strickland, 1988]. Thus, TQM is more than an attempt by DoD to improve the American industrial posture; it also focuses on improving DoD internal products and processes. Declining budgets, force reductions, and increasing external scrutiny are but a few reasons for DoD to internalize the TQM philosophies. In the future, the DoD (in particular DoD Acquisition), must do more with fewer resources. This challenge requires improved productivity which is an end product of continuous process improvement and a basic tenet of TQM. In 1988, Robert Costello, Undersecretary of Defense for Acquisition, stated, "I am making TQM success my primary objective" [Costello, 1988]. Initiatives such as acquisition steamlining, statistical process control, value engineering, and warranties are now under the TQM umbrella due to their impact on quality in the acquisition arena. By examining DoD acquisition further, we can elaborate on the TQM acquisition goals of internal quality of processes and external quality of products.

Internal quality implies efficient processes and open communication channels to enhance how the DoD gets the job done. It means empowering personnel to become more effective and efficient. Internal quality is necessitated by a decrease in available resources. The basic purpose of TQM is not necessarily to eliminate jobs and functions. However, during mandated reductions, TQM provides a means to objectively accomplish the task. The resulting organizational environment is characterized by less non-value-added work, quick and efficient job processes, and higher quality output. In acquisition this means fewer reporting channels, fewer levels of review, and a streamlined procurement process. TQM makes better use of personnel resources, ensures less redundancy of effort, and promotes smarter business practices in the execution of acquisition programs.

Improving the quality of external products means improving the products (e.g., contract proposals and specifications) the DoD acquisition community provides to industry, a DoD customer. The DoD must correctly define the systems required to provide necessary combat capability. These definitional efforts must integrate the user requirements, engineering design and design support characteristics, manufacturing concerns, and logistics support attributes. The end result is a product which allows industry to return a quality weapon system or equipment. Thus, quality is "conformance to correctly defined requirements satisfying customer needs" [Strickland, 1988], and that customer need is combat capability.

III. INTEGRATED PRODUCT DEVELOPMENT

As a result of the 1988 Institute for Defense Analyses (IDA) report, "The Role of Concurrent Engineering in Weapon System Acquisition," CE was formally adopted as DoD and TQM doctrine. The accepted definition of CE is:

> ... a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers from the outset to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements [Winner et al., 1988].

A CE approach (hereafter referred to as IPD) to design requires increased teamwork, particularly between engineering and manufacturing activities. In fact, "as practiced in Japan, [concurrent design] is a group process where members of the group represent interests spanning the life cycle of the product" [TAT, 1988]. This teamwork approach is new to some American industries. One might argue to the contrary, citing the "tiger team" concept as a prime example of teamwork in U.S. Industry. However, in general, design has not been accomplished using the multifunctional team advocated by IPD and employed in Japan. One characterization of American design is a design organization of separate functional offices that pass partial designs "over-the-wall" to the next office in the design sequence. Communication among designers is very formal and inter-departmental. A group only sees the design when the preceding group is finished with its portion of the design. IPD removes these walls and requires continual interaction between teams. Such team efforts work in IPD and are the cornerstone of TQM. The teamwork concept is successful because it empowers the people to make the necessary changes to meet the challenges facing the organization. Taken together, the initiatives share three goals, as set forth by Dr. Costello [Costello, 1989b] namely: (1) increased quality of weapon systems, (2) reduced cost (procurement and life-cycle cost), and (3) reduced development time.

Essentially, IPD is a philosophy of product design which emphasizes: (1) coordination between interdependent design activities, (2) better support and tracking of product evolution, and (3) simultaneous consideration of all product life-cycle elements. It is a basic systems engineering (MIL-STD-499) approach to design: bring the affected parties into the design process early, resolve life-cycle design issues early, and save money over the product life cycle while reducing design time through fewer changes later in the program (when such changes affect formally established program baselines).

IV. TENETS OF TQM

The key characteristics of TQM vary from author to author and expert to expert. Deming's 14 points for management [Deming, 1986] and Juran's Trilogy [Juran, 1989] are two well-known tenets. Characteristics of quality are provided by Tuttle [Tuttle, 1989], Strickland [Strickland, 1988], or any of the variety of consulting firms that provide TQM training, facilitation, or consultation support. The following key characteristics apply to both TQM and IPD:

- management commitment,
- continual improvement,
- customer satisfaction,

- teamwork,
- focus on work processes,
- training, and
- people as the critical resource.

Management Commitment

Dr. W.E. Deming and Dr. J. Juran both emphasize the crucial role of management in successful quality improvement efforts. Management must create and foster an organizational climate for TQM in which people can focus on quality and the continuous improvement of products and processes. Managers must become coaches and provide workers the requisite tools to accomplish their assigned jobs. Management sets the strategic vision and goals for the organization so that the entire organization, down to each individual worker, can relate their daily efforts to the organizational mission. These defined goals are not a method of Management by Objectives involving quota systems, nor an approach in which management defines and assigns the work tasks within the organization. Rather management's goals for the organization provide the "constancy of purpose" [Deming, 1986] for the organization; the organization's commitment to stay in business for the long run and for the welfare of all involved. Setting such lofty goals is a challenge that requires a very real commitment to the strategic planning and quality improvement process. This commitment requires cultural change on the part of management and this cultural change is one of the biggest challenges facing the TQM initiative.

IPD can be classified as a grassroots approach to systems engineering because its procedures are so "common-sense." However, in some cases the American design community has developed a tradition somewhat counter-cultural to IPD. For IPD to work effectively, there must be teamwork among the design team members, open lines of communication among the team and through the design organization, and a commitment on the part of management to give the IPD team the time and resources necessary for successful design efforts. However, American industry has created functionally aligned, stovepipe design organizations characterized by independent specialized areas, formalized communication channels, and intense management scrutiny. For IPD to succeed, these organizations must restructure and management must allow a new organizational culture to evolve. Management must create a climate in which a TQM philosophy and IPD approach to design can flourish. Management must set the goals for the system design, align the organization for successfully concurrently engineering the system, and empower the individuals involved in the design effort to make the required system design a reality. Management must share their power with the individuals of the organization; this requires a strong commitment.

Continual Improvement

A TQM environment is characterized by the philosophy, "improve it." However, in design, one might say, "Best is the enemy of good enough." While there may at first seem to be a conflict between TQM and IPD in regards to continual improvement, there really is not.

In an organization committed to quality and continual improvement, there is the understanding that all processes, and the procedures governing those processes, can and should be subject to continual improvement efforts. The improvement may simply involve accommodating new technology, but it is still improvement. In a sense, continual improvement is necessary to keep processes at their highest level of efficiency. Complacency is the archenemy of a continual improvement process [Imai, 1986]. The improvement process targets Deming's "hidden factory" [Deming, 1986] embedded within every organization. This hidden factory comprises those costs which fail to show up on the company balance sheet. The hidden factory is responsible for the scrap and rework within the organization, from the reaccomplishment of poorly machined parts to the restaffing and reprinting of incorrect correspondence. The hidden factory takes a good portion of the operating budget, particularly when considering the cost of an individual's time. Efforts to reduce a 15 percent (of gross income) hidden factory to a five percent hidden factory increases profits ten percent without any additional outlay of resourses. The continual improvement culture simply improves the processes and procedures.

IPD requires continually improving the processes by which the system is designed and manufactured to produce better designs more efficiently. Continual improvement does not necessarily mean continually improving the design characteristics and attributes of the system. Such activity will never field systems. The crux of the IPD initiative is to continually improve the processes by which systems are built; that is, improve the design of the design process. The end result is improved system functional performance with reduced development time and cost. Just as there is a hidden factory within an organization, so there is a "hidden design factory" within the design organization. Failure to properly consider certain critical aspects of a system design (as one example) can lead to costly redesign later in the manufacturing process. Later redesign is even more costly once baselines are established and mock-ups and prototypes are developed. Early consideration of pertinent design issues reflects a preventative approach to system design. Finding new and improved ways to reduce the hidden design factory requires an organizational environment conducive to change for improvement. This same environment incorporates lessons learned into the design process so the organization can learn from previous experiences.

Cultural changes are an accepted part of the TQM effort. A continuous improvement environment within design also requires cultural change. An environment that encourages a questioning attitude challenges the old methods of design and examines potential improvements. It requires a shift in attitude so the design process uniquely fits the system under design. Such cultural changes require management commitment as well as a focus on the work processes under continual improvement.

Customer Satisfaction

One of the strongest TQM/IPD links is the focus on the customer and his/her requirements. In any organization, dissatisfied customers mean loss of business, loss of market share, and loss of profit. As these losses add up, the business will ultimately cease to exist (if it does not change its approach). The customer wants quality products at a just price. In the customers eyes, the product must be free of defects and not promote dissatisfaction. Quality motivated firms develop close ties to their customers. An MIT study on industrial competitiveness noted, "the best practice firms we observed are developing closer ties to their customers" [Berger et al., 1990].

In TQM, part of the change in organizational culture that affects the customer focus is the recognition of the alternating roles of customer and supplier, both at the process and organizational level. In every process, input is received (functioning as a customer) and output is produced; this output is then used by someone else (functioning as a supplier). Understanding this customer-supplier cycle is important. To improve the quality of a process, the process owner must understand and communicate, his requirements to his supplier. Further, he must understand and meet the requirements of his customer when functioning as a supplier. This same relationship holds for organizations. A company receives input (raw materials, specifications, task plans) and produces output (finished products, systems, technical publications). For these reasons, TQM advocates closer ties with suppliers to communicate requirements and improve the quality of the input received so as to improve the quality of the output produced at both the individual process and organizational level. This is a definite change in American management philosophy which typically advocates the "arms-length" approach to maintain emphasis on competition.

While not replacing competition, there must come a more unified, teaming philosophy among companies to promote satisfaction of requirements.

The entire design process starts with the definition of the customer, or in the DoD case, the operational user requirements. The IDA report on CE states, "CE starts with the requirements generation process... [and is] characterized by a focus on customer requirements" [Winner et al., 1988]. The definition of DoD system requirements, coupled with improved design processes, are key elements in an IPD design effort. These elements strive to develop systems in line with operational user needs. One objective is to improve the operational suitability[2] of the fielded system. Systems must meet the needs of the user while the design and acquisition processes must produce and deliver the system "in time" to apply the system to the required combat capability.[3] To accomplish this task, users must be involved throughout the process, from defining the required capability, to defining the acquisition and developmental requirements, to providing timely feedback throughout the development and support process.

The bottom line for achieving customer satisfaction in weapon systems is combat capability. The end user needs capable systems and equipment; there is no room for poor designs. Customer satisfaction requires quality system (or product) attributes and system operating characteristics that cause the end user to "want" the system because it provides what is needed--combat capability.

Teamwork

According to Juran, the road to quality is traveled project by project [Juran, 1989] and each project is accomplished by a project team. Teamwork is important for successful TQM implementation, particularly in realizing the incremental changes from each project contributing toward a continual process improvement environment. Projects arise from within the organization with a recognized need for a process improvement effort. Both management and the organizational structure must promote such teaming activities. No longer can American management dictate all activities within the organization. The

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[2] Operational Suitability is "The degree to which a system can be placed satisfactorily in field use, with consideration being given to availability, compatability, transportability, interoperability, reliability, wartime usage rates, maintainability, safety, human factors, manpower supportability, logistic supportability, and training requirements.

[3] The "in-time" concept implies delivery of the system according to the agreed schedule reflecting when the system is needed by the operational user.

American management ethos must change to Participative Management, Cross-Funtional Management, or some form of these as the accepted method of management.

In these quality based approaches, the organizational structure flattens. Strict functional alignments found, in vertically structured organizations, are removed and the organization becomes more unified. Flatter organizational structures promote cross-functional teamwork to address issues and processes that impact the entire organization. Less restrictive communication results from removing barriers between work areas. Employees can work together to improve the supplier-customer relationships on the job-shop floor. A Just in Time inventory system is one example of teamwork, not only among the companies involved in supplier-customer relationships, but also among the job-shop workers in a production facility. A flatter organizational structure improves communication through the organizational hierarchy; management listens to what the work force is saying rather than telling the work force to "listen up" during one-way, downward-directed communications.

As previously mentioned, IPD requires a team approach to design. Technology is important to efficiently design and analyze increasingly complex weapon systems, but technology is not the total answer to improving the design process. Early conceptual design involves many issues, thus it requires a multidisciplined team, pulled from the entire organization and chartered to address issues impacting the overall system lifecycle. While early design details may often preclude detailed decision-making due to risk and uncertainty in the eventual system characteristics, issues such as logistics support, maintainability, manpower, personnel, and training should be considered early to avoid later conflicts as the system design evolves and the system characteristics become more defined. This IPD-team approach requires a project-teaming organizational structure characterized by open communication among team members, access to evolving design information, clear and concise reporting channels to management, and commitment to the project versus commitment to the functional "home" office.

The IPD teaming concept is extensible to contract-subcontractor relationship as organizations work together to improve their product and processes. Subcontractors provide components to the contractor who integrates the components to form the system. The better the subcontractor produces in terms of conformance to specifications, quality of workmanship, and adaptability to the integrated system, the more efficient and effective the integration task. Working as a team to effectively communicate the requirements of the system development project allows for an efficient subcontractor-to-contractor flow of products. This in turn enhances the system design and integration process to ultimately improve the quality of the system, or equipment, delivered to the DoD customer.

Work Processes

All efforts are made up of processes; improving these processes will produce better products and a healthier organization. Both TQM and IPD share this vision and purpose.

Any organization, whether a manufacturing firm, a service organization, or a consulting firm, accomplishes its mission via processes. Within these processes are the hidden factory previously discussed. This hidden factory costs the organization money without generating income or adding value to the organization. Reducing the level of the hidden factory by improving the work processes increases profits. A climate of continual improvement evolves through a focus on the work processes. Each worker should be knowledgeable in his/her work process and those processes that affect his/her own process. This will provide him/her the ability to ask and address the question, "Is there a better way?" Management must allow workers to openly question the current standards, and form teams to examine and improve the work processes. With the increased emphasis on improving productivity must come the realization that true increases in productivity result from improving the processes, not controlling and managing according to the numbers or output of the processes. Furthermore, by improving the work processes, management can build flexibility into the organization; flexibility needed to cope with rapid change caused by increasing system complexity and changing technology.

To some researchers, design is merely a process of making design decisions [Mistree, 1990] and the purpose of the design team and design project managers is to manage the design decision process. Project managers must focus on the design process, not manage according to the products of the design effort. Naturally, the design schedule in large part dictates management concerns, and the schedule typically focuses on the products. While schedule concerns are indeed very important, IPD requires managers to shift some emphasis to the design process and how schedules support the planned design decision sequence.

IPD brings tremendous potential to the development process [Winner et al., 1988]. More knowledgeable designers are part of the process. Since the designers must address the wide range of technical issues pertinent to each system design. The design process and the design personnel must be capable of handling the increasing level of complexity. This is particularly true with fewer weapon systems under development. With fewer systems in the pipeline, and each system requiring so long to design, build, and acquire, one pitfall to avoid is to get all the technology inserted into the system. Such technology can come from many sources. For instance, laboratories want to insert their new, state-of-the-art technology into the system. The design engineers may wish to insert technology they are familiar with though there may not be a strong need for it. In either case, the laboratory and the engineer cause technology to drive the system design process. In reality, the design process must efficiently and effectively design and build the requested system within the decreased development time promised by the IPD design approach. IPD can reduce development time through the early identification and resolution of life-cycle concerns for the system. Early identification and resolution of problems avoids costly, and time-consuming, redesign and rework later in the effort. Studies indicate up to 70 percent of life-cycle cost drives are locked into the system after just 20 percent of the development time has been expended. This 70/20 relationship provides IPD the potential to reduce cost and development time, and increase quality through an improved design process.

Training

Two of Dr. Deming's Fourteen Points deal with training: Point 6 - institute training on the job, and Point 13 - institute a vigorous program of education and self-improvement [Scherkenbach, 1988]. In particular, in Japan's Kaizen philosophy [Imai, 1986], management builds a quality-based organization through training and leadership. Workers are responsible for their particular work process but they must be trained to properly accomplish the task. Training on the job is just as important as the physical tools required to accomplish the job. Truly comprehensive training includes instruction in other aspects of the job-floor or organization. In many progressive organizations, the training program includes job rotation. This not only provides a more qualified, robust workforce, it also builds unity within the work force as workers gain an understanding of other teammembers' duties and responsibilities. Training in statistical and problem solving tools may also be provided. An organizational culture focused on continual improvement needs personnel with the requisite skills to implement the identified improvements. Training in problem solving enables the work force to not only identify improvement opportunities, but also to analyze and determine improvement strategies for the work process. Deming's Point 13 focuses on enhancing the capabilities of the individual. Focused training is required for any job. However, for the employee to grow as an individual and better accommodate change, he/she must be allowed to learn new skills that may or may not have direct application to his/her immediate tasks. This produces workers with more diverse backgrounds who are more open to change and more dedicated to the organization since the organization gave them the chance to branch out in their own direction. The result is a more qualified work force.

The same training philosophy holds for the design team within the IPD design environment. The organization must provide the training to bring the design team to the appropriate level of technical proficiency. The design team needs training to understand the basic roles and functions of each member of the team. Technical depth is often not required in all subject areas, but a cursory knowledge of the various functional areas within the design effort is a plus. Design teams face increasingly complex systems and they must simultaneously address more design issues early in the design process. Members of this multidisciplined design team need improved methodologies, techniques, and analytical tools to handle this complex decision process. Along with the methods and techniques, members must have sufficient training to effectively employ the tools. A well-rounded design organization is more open to changing environments and changing technologies. A narrow approach to training prevents, or stifles, adaptation to new or improved design processes. A broad-based training program which focuses on individual needs and desires is the best overall training approach.

People as the Critical Resource

Every quality initiative recognizes that people are the most valuable resource of any organization. Management alone is not responsible for improving and guiding an organization. If management represents ten percent of the organization, 90 percent of the organizational brainpower is ignored. The alternative organizational approach embraces continual process improvement and puts 100 percent of the organization's brainpower to work improving and guiding the organization. The organization empowers its employees to identify areas for improvement and then work to achieve those improvements. This focus on process improvement is characterized by an emphasis on the people within the process.

People can adapt and reason and thus can handle change and complexity. Machines and computers deal with algorithmic reasoning which requires structured problems defined by rules and conditions; reality is not always so structured. The ability to infer knowledge from seemingly disjointed pieces of information is a human task. Japanese manufacturing success proves that human workers can function in a highly productive manner [TAT, 1988]. Adaptive manufacturing and improving the manufacturing process, both off-line and on-line, is still best accomplished by humans. Outside the manufacturing environment, people are even more important when dealing with the unstructured decision processes characteristic of daily operations.

The IPD initiative differs from other design improvement initiatives in that it focuses on the human designer in the design process. Weapon system design is, and always will be, heavily dependent on computer technology to handle the numerous and highly complex design aspects, constraints, drawings, and analyses. However, IPD recognizes that ultimately, the design decision process is accomplished by the members of the IPD team. The concept of a multidisciplined team collectively addressing life-cycle issues for the system, and making decisions regarding system tradeoffs, technologies, complexities, and attributes stresses the importance of qualified and motivated individuals within the design team. Management must provide the design team:

- tools to accomplish the analyses upon which to base design decisions,
- training to understand the design process and the interrelationships among the design aspects,
- training to allow the individuals to work together in a team environment as well as improve the design processes, and
- an organizational environment conducive to open communication among the design team members and up through the project management structure.

Design is basically a human activity. It has been characterized as the management of a sequence of design decisions or as a learning process in which the design team, learning from each decision, gains an understanding of the evolving design. Regardless of its characterization the process is a people process.

A final quote, again from the MIT Productivity study, captures the essense of this TQM tenet:

> In a system based on mass production of standard goods, where cost matters more than quality, the neglect of human resources by companies may have been compatible with good economic performance; today it appears as a major part of the U.S.'s productivity problem [Berger, et al., 1989].

V. CONCLUSIONS

This paper discussed the similarities between TQM and IPD, and characterized IPD as TQM for product design. The similarities are valid. Both TQM and IPD require a cultural change for successful implementation, but what is a cultural change? Once defined, how does the organization know when the culture has changed? The best measure is the output. If the output indicates organizational health, and the organizational philosophy is one of continual process improvement, does this imply successful organizational cultural change? These are questions everyone involved in TQM or IPD must address.

The communication process within the IPD team is critical for successful IPD design efforts. With personnel drawn from various functional disciplines, speaking the respective technical languages, communicating design concepts can become over-complicated and unwieldy. The communication process must be open, unimpeded by formal organizational concerns. Management must create this communication process and allow the design team to evolve and improve on it during the design process.

TQM promises to improve an organization, thereby improving the products and processes it comprises. In the commercial sector, this improvement is necessitated by increasing global competition and loss of market share. In the DoD, in particular the acquisition community, the challenge is to achieve more with less as well as help ensure the economic health of the industrial base. Among the implied goals of TQM are: (1) improved quality, (2) reduced cost, and (3) shortened schedules.

IPD is a powerful tool to help achieve the TQM goals for acquisition. Success for IPD is predicated on many of the same conditions placed on the TQM initiative; this was the motivation for this paper. Each initiative is based on similar tenets characterized overall by: management commitment, involvement of the entire organization, open channels of communication, and a philosophy of continual improvement of products and processes.

There is no blueprint for success in either initiative. Every organization and each individual within it is unique, thus necessitating unique approaches to training, organizational and process improvement, teamwork and teambuilding, and shifting the focus to quality. Deming's Fourteen Points provide solid philosophy, but they are not a "how to" list. Juran's management structure for quality describes how to organize the quality improvement effort, but not how to accomplish the transformation. There are many consultants offering TQM services, each with their own "canned" approach, but each approach must still be tailored to the target organization.

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